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INCREMENTS OF PLASTIC STRAIN AND HARDNESS HV10 OF AUTOMOTIVE STEEL SHEETS

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The present paper deals with measurements of the increments of strain and hardness HV10 on automotive steel sheets. The car body manufacture trends are focused, in particular, on high energy absorption capability. In the manufacture of a car body, there are requirements for high plasticity and homogeneity of the pressed sheets. The measurements were made on DP steel, micro-alloyed steel, and IF steel. The increments of strain were measured around V notches. The specimens were scanned using a video-extensometer technique with a CCD camera. The result was strain increment maps, constructed using the Matlab software. The hardness HV10 was measured on the failed specimens around the notches. 3D hardness distribution maps were made from the measured values of HV10.

Key words: videoextensometry, automotive steels, strain field maps, strain rate

Porast plastične deformacije i tvrdoće HV10 automobilskih limova. Ovaj rad bavi se mjerenjima porasta deformacije i tvrdoće HV 10 automobilskih limova. Trendovi proizvodnje karoserija su usmjereni, osobito, na visokim sposobnostima apsorpcije energije. U proizvodnju karoserija, postoje zahtjevi za visokom plastičnosti i homogenosti prešanih listova. Mjerenja su provedena na DP čeliku, mikro-legiranom čeliku. Porast deformacije mjerena su oko V zareza. Uzorci su skenirani rabljenjem videoextensometer tehnike s CCD kamerom. Rezultat porasta je deformacijska karta, ustrojena korištenjem Matlab program. Tvrdoća HV10 mjerena je na uzorcima u okolini zareza. 3D karte tvrdoće su izrađene na temelju izmjerenih vrijednosti HV10.

Ključne riječi: videoextenzometrička metoda, automobilski limovi, deformacijske karte, brzina deformacije

INTRODUCTION

The current trends in the manufacture of car bodies are focused, in particular, on the requirements for high energy absorption capability in case of an accident. From the aspect of technology, i.e. manufacture of pressings and car bodies, requirements for very high plasticity and homogeneity of properties are emphasized. There is a relatively pronounced relationship between the strength properties and the plasticity properties, characterized by increasing yield point and tensile strength values. The requirements for material properties of individual car parts and components are different. They are gradually specified and the related research at metallurgical manufacturers leads to the development of specialized products for a narrow area of application. IF steel, DP steel, and micro-alloyed steel HR 45 also fall under the category of automotive sheets. IF steel (interstitial free steel) has a high elongation, which is achieved through a very low content of interstitial atoms, a suitable ferrite grain size, and a favourable texture formed during the recrystallization annealing [1-4] DP steel (dual phase steel) has a ferrite and martensitic microstructure, a continuous yield point, a higher tensile strength, a higher plasticity and formability. A characteristic feature of dual phase steels is their structure, which consists of 70-90 % ferrite and 10-30 % martensite [5, 6]. Micro-alloyed steels are known under the abbreviation HSLA (High Strength Low Alloy) steels. Their required properties are mainly achieved through a suitably chosen thermo-mechanical treatment. Their favourable properties include an increased yield point, good toughness (even at low temperatures), and guaranteed weldability [7]. The presence of notches – and even of smoother changes in geometry, results in a very complex stress distribution when compared with simple-shaped components. The experiment was focused on the determination of the effect of the V notch on the strain distribution [8].

MATERIAL AND EXPERIMENTAL METHOD

Experimental material: IF steel with a gauge of 1,6 mm, DP steel with a gauge of 1,5 mm, and micro-alloyed steel HR 45 with a gauge of 1,8 mm. The mechanical properties of the tested steels are shown in Table 1. The dimensions of short test specimens were in accordance with STN EN ISO 6892.

Figure 1 shows a V-notch test specimen. A video-extensometer technique was used for the experiments.

The specimens were fixed in the tensile machine and the whole test was recorded using a camera, Figure 2.

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Table 1 **Mechanical properties of used materials**

Materials	Mechanical properties		
	$R_{p\,0.2}$ / MPa	R_m / MPa	A / %
HR 45	369	464	18
IF	185	300	36
DP	415	631	24

Contrast marks were painted in the working area of the specimen with the raster of 1 x 1 mm, Figure 1(black dots on the light surface of the specimen create the required contrast). The increments of strain can be evaluated by continuous scanning in a time and by recording the coordinates of the centres of gravity of these dots using dedicated software. During loading the specimen, the position of the dots and the distance between them change. The Dot – Measuring software evaluates the displacements of dots. The data were processed using the VDTK software, which is a superstructure of the MATLAB software [9, 10]. The output of this software is a strain map.

The hardness HV10 was measured on the failed specimens in the marked dots, in which also strain increments were calculated. The measured HV10 values were evaluated graphically using Microsoft Excel. The result was 3D hardness graphs. The individual colours represent different values of hardness HV10; the black colour represents the highest values, while the blue colour represents the lowest values of hardness HV10.

Table 2 shows maximum measured values of hardness HV10 and maximum values of increments of strain ε_y for all the investigated steel grades.

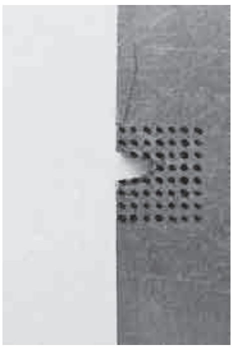

Figure 1 Specimen with V notch

RESULTS AND DISCUSSION

For IF steel Figure 3, DP steel Figure 4 and microalloyed steel HR 45 Figure 5, strain maps were constructed, showing longitudinal strain increments ε_y for V-notch specimens.

Table 1 indicates that the IF steel has the lowest R_m and the highest elongation. The highest elongation was also demonstrated by the strain maps, where the IF steel had the highest strain increment of all the three tested materials – 100 %, Figure 3. The DP steel had the highest tensile strength, which was also demonstrated by the highest hardness HV10 – 216, Figure 6.

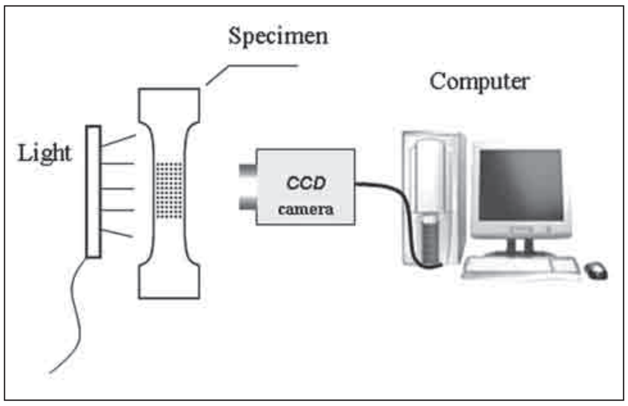

Figure 2 Scheme of videoextensometry

Table 2 **Measured values of hardness HV10 and maximum values of increments of strain ε_y investigation steels**

V notch	Measured values	
	max. hardness / HV10	max. increments of strain ε_y / %
IF	144	100
DP	216	35
HR 45	206	45

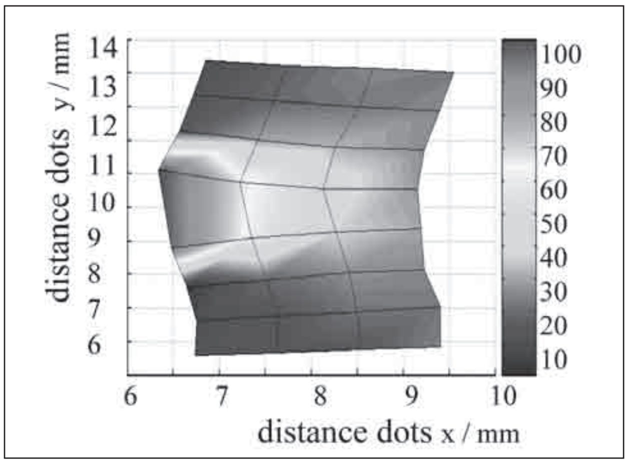

Figure 3 Strain field map ε_y for steel IF

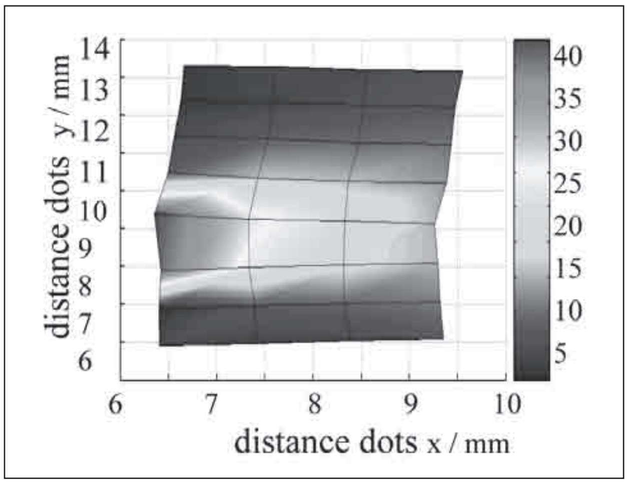

Figure 4 Strain field map ε_y for steel DP

The highest values of hardness HV10 for IF steel occur in a close vicinity of notches Figure 7, for HR 45 steel Figure 8 after their failure. It can be stated that increasing

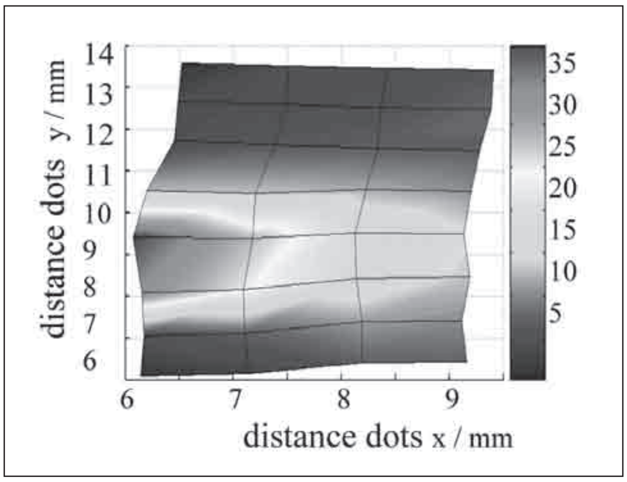

Figure 5 Strain field map ε_y for steel HR 45

values of the increment of strain ε_y result in strain hardening for almost all of the materials, which was demonstrated by the measured values of hardness HV10, while this fact is the most significant for the IF steel.

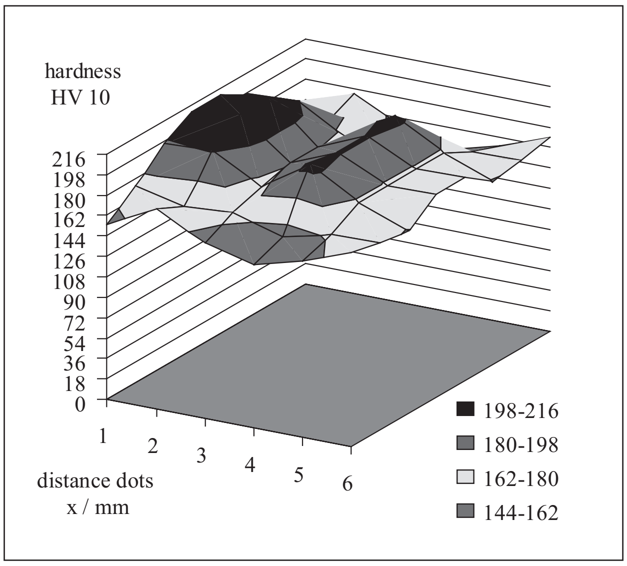

Figure 6 HV10 map for steel DP

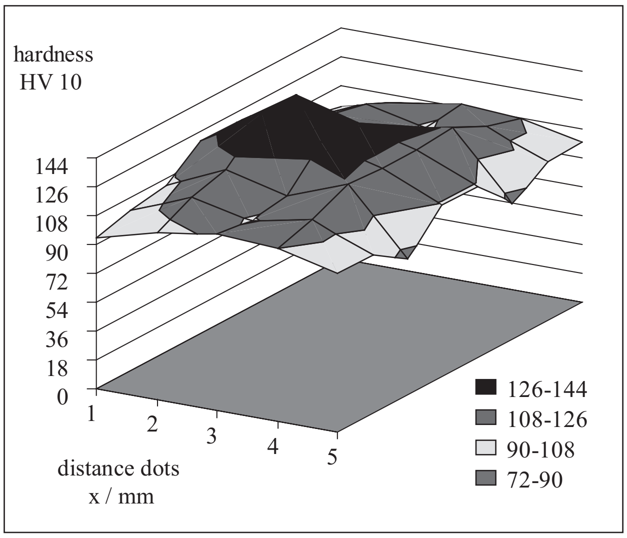

Figure 7 HV10 map for steel IF

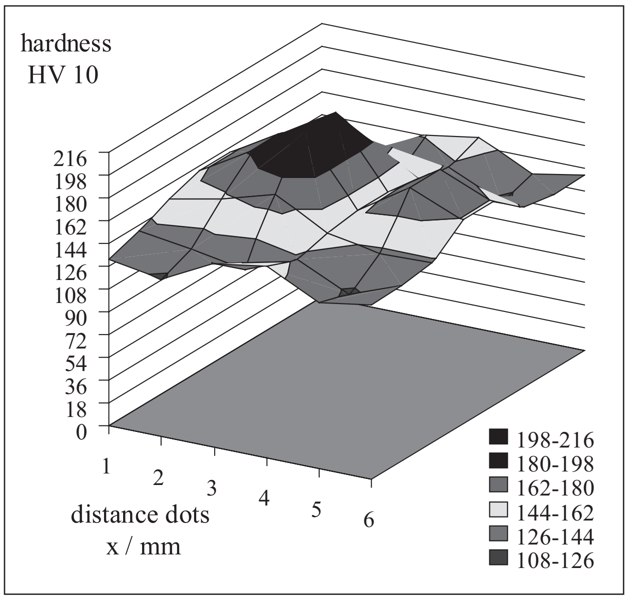

Figure 8 HV10 map for steel HR 45

CONCLUSIONS

In the paper, three automotive steel grades were analyzed. Their behaviour in the deformation processes was investigated. The focus was made on the effect of the V notch.

The following can be stated:

- Strain maps were constructed for the IF steel, the DP steel and the micro-alloyed steel, showing longitudinal strains $\boldsymbol{\varepsilon}_y$ for V-notch specimens.
- It results from the strain maps that the highest increments of strain occur in a close vicinity of the notch roots for all the used materials.
- For the IF steel, the maximum measured increment of strain was $\boldsymbol{\varepsilon}_y$ 100 % and the maximum measured hardness was 144 HV10.
- For the DP steel, the maximum measured increment of strain was $\boldsymbol{\varepsilon}_y$ 35 % and the maximum measured hardness was 216 HV10.
- For the steel HR 45, the maximum measured increment of strain was $\boldsymbol{\varepsilon}_y$ 45 % and the maximum measured hardness was 206 HV10.

In conclusion, it can be stated that increasing values of the strain $\boldsymbol{\varepsilon}_y$ result in strain hardening for all of the materials, which was demonstrated by the measured values of hardness HV10, while this fact is the most significant for the IF steel.

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